It is important to note that the decline in output growth can have a particularly debilitating effect on TFP performance if the declines are concentrated in "high margin" services, such as access and toll. This is particularly important in California, where intraLATA toll markets were opened to competition this year. Pacific Bell faces the prospect of lower TFP growth as competition and bypass lead to reductions in toll and access output growth. This is in addition to the dampening effect of the California economy's slowdown on Pacific Bell's performance.

In summary, not only does the overall decline in Pacific Bell's output growth portend lower performance in the future, but the fact that high-margin services are exhibiting output growth declines will have a disproportionately negative impact on Pacific Bell performance. This indicates that achieving performance on par with industry averages will be a challenging goal for Pacific Bell over the near-term future.

Appendix 1

"Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation 1993 Update"

by

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Philip E. Schoech

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Productivity of the Local Operating Telephone Companies

Subject to Price Cap Regulation

1993 Update

Laurits R. Christensen, Philip E. Schoech,

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Christensen Associates

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Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation 1993 Update

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1. Introduction

This report updates through 1993 the Total Factor Productivity study of the price cap Local Exchange Carriers (LECs) that Christensen Associates performed for the United States Telephone Association (USTA). Total Factor Productivity (TFP) is the ratio of total output to total input, where total output includes all services provided by the Local Exchange Carriers and total input includes the capital, labor, and materials used to provide those services.[1] The companies included in the study are Ameritech, Bell Atlantic, BellSouth, GTE, NYNEX, Pacific Telesis, Southern New England Telephone, Southwestern Bell, and U S West. The original study covered the period 1984-1992.[2] Data are now available to include 1993 in the study.

The results of the updated study are that over the 1984-1993 period, total output for the price cap LECs grew at a 3.4 percent average annual rate and total input grew at a 1.0 percent average annual rate, resulting in average annual TFP

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[1]Total output consists of all services included in total operating revenue, as currently defined in the Form M.

[2]"Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation," Christensen Associates, May 3, 1994. Hereafter referred to as the "1984-1992 study."

growth of 2.4 percent. The productivity offset in the price cap formula is related to the differential in productivity growth between the LECs and the U.S. economy. Given that economy-wide TFP growth has averaged 0.3 percent annually between 1984-1992,[3] LEC post-divestiture TFP growth has exceeded economy-wide TFP growth, with a TFP growth differential of 2.1 percent.

The methodology employed in this study was initially developed for our 1981 study of the Bell System,[3] and subsequently has been applied in studies submitted to and accepted by the public utility commissions in North Dakota, Georgia, Illinois, Ohio, and Indiana. It is based on research conducted by Laurits Christensen and Dale Jorgenson into the measurement of TFP growth in the U.S. economy.[4] The data requirements of the methodology are met with company records and, in fact, most of the required data are filed annually with the Federal Communications Commission.

To measure total output, seven different types of services are distinguished: local service, interstate end user access, interstate switched access, interstate special

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[3]The economy-wide TFP figure is based on the U.S. Bureau of Labor Statistics' measure of "multifactor" productivity for the private business sector of the U.S. economy. Bureau of Labor Statistics multifactor productivity measures are reported in the BLS publication, Monthly Labor Review.

[3]Laurits R. Christensen, Dianne C. Christensen, and Philip E. Schoech, "Total Factor Productivity in the Bell System, 1947-1979." Christensen Associates, September 1981.

[4]L.R. Christensen and D.W. Jorgenson, "The Measurement of U.S. Real Capital Input, 1929-1967," Review of Income and Wealth, Series 15, December 1969, pp. 293-320; L.R. Christensen and D.W. Jorgenson, "U.S. Real Product and Real Factor Input, 1929-1967," Review of Income and Wealth, Series 16, March 1970, pp. 19-50; and L.R. Christensen and D.W. Jorgenson, "U.S. Income, Savings and Wealth, 1929-1969," Review of Income and Wealth, Series 19, December 1973, pp. 329-362.

access, intrastate access, long distance service, and miscellaneous services. Price changes are factored out of each category's revenues to obtain quantity indexes. The quantity indexes for the revenue categories are aggregated into an overall output quantity index.

The weights used in the computation of the output index are the revenue shares of the services contained in the index. For purposes of determining the productivity offset in a price cap formula, this is the proper specification for the output index. By employing the revenue weighted output index, prices paid by LEC customers can be linked to changes in input price inflation and changes in TFP.[5] Proper specification of the output index is important because changes in output growth are directly related to changes in TFP growth.[6]

Total input is comprised of capital (plant and equipment), labor, and materials (purchased materials, rents, and services). To construct a quantity index of total input, we first construct separate quantity indexes for capital, labor, and materials. The capital, labor, and materials quantity indexes are then aggregated into an overall input quantity index with cost shares serving as the weights for the input categories.

To measure capital input, six asset classes are distinguished: buildings, general support equipment, central office equipment (including operator systems), transmission equipment, information origination/termination equipment, and cable and

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[5]This relationship is formally presented in Appendix 1 of the 1984-1992 study.

[6]Chapter 2 of the 1984-1992 study explores in detail the relationship between output growth and TFP growth.

wire. Quantity indexes and annualized costs are calculated for each of the asset classes; then an overall quantity index of total capital input is computed from the asset classes, with their cost shares used as weights.

Labor input is the time spent by LEC employees in providing services to LEC customers. It does not include the time spent installing plant and equipment, since this time is included in the capital input measure. Two groups of employees are distinguished in the study: management and non-management. The quantity index of labor input is an index of management and non-management hours worked, with management and non-management labor cost shares used as weights.

The cost of materials is equal to total operating expense less depreciation and payments to labor. Since this category is comprised of a diverse set of inputs, the U.S. Gross Domestic Product Price Index (GDPPI) is used to represent the price of materials. The quantity index of materials is obtained by dividing materials cost by its price.

Section 2 describes the methods to calculate total output. Section 3 describes the methods to calculate total input. In Section 4, we present the annual figures for total output, total input, and Total Factor Productivity for 1984-1993. Most of the data used in the computations come either from the Form M annual reports filed with the FCC or were supplied to us directly by the LECs. We have reviewed all data to ensure that they are reasonable and appropriate.[7]

[7]It should be noted that in addition to obtaining 1993 data for the study update, some data were revised by the participating companies for the 1984-1992 period.

2. Total Output--Methods

The Local Exchange Carriers provide a variety of telecommunications services; consequently LEC output cannot be adequately measured using simple physical indicators such as access lines, number of calls, or minutes of use. To properly measure output, different types of LEC services must be distinguished, and for each service category, price and quantity indexes must be developed that accurately represent the complexity and diversity of telephone operations. We measure seven major categories of services: local service, interstate end user access, interstate switched access, interstate special access, intrastate access, long distance service, and miscellaneous services. For each of these service categories, a price index is constructed to represent price changes that occurred during the study period. The price indexes are used to factor price changes out of each service category's revenues, yielding an output quantity index for each service category.

Output by Category

The company Form M annual reports show booked revenue for each of the service categories listed above. When using these data, it is important to make adjustments for changes in accounting definitions. In particular, the mandated accounting revisions in 1988 must be addressed.[8] The primary difference between reported operating revenue through 1987 and reported operating revenue beginning

[8]This is the Uniform System of Accounts Rewrite, or USOAR, which was mandated by the FCC and implemented in 1988.

in 1988 is revenue from certain nonregulated services. Beginning in 1988, all revenue from nonregulated services that had joint and common costs with regulated services were reported in operating revenue. Before 1988 this was not the case. The LECs provided Christensen Associates with adjustments to the Form M booked revenues for the 1984-1987 period in order to put revenues from the two periods (1984-1987 and 1988-1993) on a consistent accounting basis. These adjustments apply to the miscellaneous services category.

Price indexes for local service, intrastate access, and long distance service are constructed from the price change information reported by the LECs in the Form M.[9] In the Form M, the LECs report the impact of rate changes in terms of changes in revenue. The methodology we use converts the dollar change in revenue to a percentage change in the overall rate level. These percentage changes in rate levels are then used to construct a price index.[10]

Because the interstate access rate change information filed in the Form M is not as comprehensive as the information filed by the companies for intrastate price changes, other methods are used to construct price indexes for interstate end user access, interstate switched access, and interstate special access. The price index for

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[9]Form M price change information for the entire 1984-1993 period was available for Ameritech, Bell Atlantic, Bell South, NYNEX, Pacific Telesis, Southern New England, Southwestern Bell, and U S West. This information was used to construct the price indexes for local, intrastate access, and long distance service in this study.

[10]Appendix 2 of the 1984-1992 report provides a detailed description of this methodology.

interstate end user access is computed as the ratio of end user access revenue to the number of access lines, where both revenue and access lines are taken from the Form M report. To compute a price index for interstate switched access, a quantity index is first computed. This quantity index is a Tornqvist[11] index of LEC common line minutes of use and traffic sensitive minutes of use, where carrier common line and traffic sensitive revenues are used as weights. Once the quantity index is computed, the price index is obtained by dividing booked revenue by the quantity index. Finally, a special access price index is developed from LEC data on prices for special access services.

For local service, interstate end user access, interstate switched access, and interstate special access, the quantity indexes are obtained by dividing booked revenue by the corresponding price index. For intrastate access and long distance service, a different approach is necessary. The reason is that the price indexes represent the prices paid by customers, while the revenue represents the revenue received by the companies. Because of the settlements process, the revenue received by the company does not equal the amount paid by the customer. Consequently, we obtain quantity indexes for these services by dividing billed revenue by the corresponding price index.[12]

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[11]The Tornqvist index determines the rate of growth of a quantity index by weighting the growth of each of the services in the index by each service's revenue share.

[12]As noted above, the price index for interstate access is constructed using booked revenues. In this case, revenue and price indexes both represent the revenue received by the companies.

Since miscellaneous services represents a wide variety of activities, the U.S. Gross Domestic Product Price Index (GDPPI) is used as the price index for this category. The quantity index for miscellaneous services is obtained by dividing adjusted booked revenue by the GDPPI.

Total Output

The quantity indexes for the revenue categories are aggregated using the Tornqvist index. The index produces an overall rate of growth in total output by weighting the growth rates for each revenue category. The weights used in the computation are the revenue shares of the categories, where the adjusted revenues described above are used in constructing the weights.

3. Total Input--Methods

Total input is comprised of capital (plant and equipment), labor, and materials, rents, and services (hereafter referred to as materials). To construct a quantity index of total input, quantity indexes for capital, labor, and materials are constructed. The capital, labor, and materials quantity indexes are then aggregated using the Tornqvist index to obtain the quantity index of total input, with cost shares serving as the weights for the various categories.

Capital

The quantity and cost of capital input is based on the Christensen-Jorgenson methodology.[13] Six asset classes are distinguished: buildings, general support equipment, central office equipment (including operator systems), transmission equipment, information origination/termination equipment, and cable and wire. The quantity of capital stock is calculated for each asset class using the perpetual inventory capital stock equation, which has the form:

$$K_t = (1 - \delta)\cdot K_{t-1} + I_t \qquad (1.1)$$

where

K_t = the quantity of capital stock at the end of year t
I_t = the quantity of investment during year t
δ = the economic rate of replacement.

The economic rates of replacement used in the study are taken from Jorgenson.[14] The rates are: 15.5% for general support equipment, 11.0% for central office equipment, transmission equipment, and information origination/termination equipment, and 2.3% for buildings and cable and wire. The quantities of investment are obtained by dividing the value of investment by the corresponding investment price deflators, also known as Telephone Plant Indexes. The LECs provided Telephone Plant Indexes for each of the asset classes, for each

[13]See Christensen and Jorgenson, 1969.

[14]D.W. Jorgenson, "Productivity and Economic Growth," in E.R. Berndt and J.E. Triplett, eds., Fifty Years of Economic Measurement (Chicago: University of Chicago Press, 1990), pp. 19-118.

year. The values of additions to plant are based on data reported in the Form M, which need to be adjusted for the USOAR accounting changes. The primary accounting change affecting the measurement of capital occurs in 1988. Starting in 1988, some expenditures that had previously been reported as additions to plant were now required to be reported as operating expense. In 1988, operating expense for the LECs increased by $2.1 billion because of these accounting changes. This figure was used as the basis for adjusting reported gross additions for the 1984-1987 period.

A starting value, or benchmark, for K must be calculated in order to apply the perpetual inventory capital stock equation. We calculate a 1984 benchmark for each asset class, based on the 1984 replacement cost as provided by the LECs. This 1984 replacement cost is a "current cost of gross plant" measure. That is, assets of different vintages are repriced to provide a common basis of valuation. It is necessary to adjust the replacement cost for the age distribution of the assets. The U.S. Bureau of Economic Analysis reports the age distribution of the relevant assets for the telecommunications industry. This industry age distribution of plant and equipment is used to derive the LEC age distribution of plant and equipment. The LEC age distribution is then used to obtain a benchmark value for each asset class. Finally, an adjustment for USOAR is also necessary for the benchmark, since the data underlying the benchmark estimate are based on the pre-USOAR accounting standards.

Once the quantity indexes are computed for each of the asset classes, they must be aggregated into an overall capital input index. The weights used to aggregate

the asset classes are the annual capital costs of each asset class (also referred to as the "implicit rental" costs). The annual cost of capital services for each asset class is calculated using the Christensen-Jorgenson methodology and includes four components: (1) the opportunity cost of the capital held in the form of plant and equipment; (2) plus cost of declines in efficiency of plant and equipment; (3) less the economic revaluation of plant and equipment; (4) plus the cost of property taxes and profits taxes.[15]

For each of the asset classes, the four components of annual capital costs are calculated as follows. First, the opportunity cost of the capital held in the form of plant and equipment is calculated by multiplying the current economic value of plant and equipment by the appropriate interest rate. The current economic value of plant and equipment is obtained by multiplying the quantity of the capital stock by the relevant Telephone Plant Index. The interest rate used as the opportunity cost is Moody's Composite Yield on Public Utility Bonds. Second, the cost of declines in efficiency is obtained by multiplying the economic rates of efficiency decline by the

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[15]See Christensen and Jorgenson, 1969. The Christensen-Jorgenson formula for the implicit rental price is:

$$v_t = [(1 - u \cdot z - k)/(1-u)] \cdot [r_t \cdot p_{t-1} + \delta \cdot p_t - (p_t - p_{t-1})] + \tau \cdot p_t ,$$

where u is the rate of taxation on income, z is the present value of tax depreciation allowances, k is the investment tax credit rate, r is the interest rate (Moody's yield on public utility bonds), p is the Telephone Plant Index, δ is the rate of economic replacement (representing the declines in efficiency), and τ is the rate of property taxation. The income tax rate, the property tax rate, and the investment tax credit rate are based on income taxes, property taxes, and investment tax credits reported by the LECs in the Form M report. The present values of tax depreciation allowances are based on the tax lifetimes and depreciation formulas specified by law.

current economic value of plant and equipment. Third, the economic revaluation of plant and equipment is obtained by multiplying the quantity of capital stock by the change in the relevant Telephone Plant Index. Fourth, the cost of property and profits taxes is based on taxes reported in the Form M.

Once the quantity indexes and costs are calculated for each of the asset classes, the quantity index of total capital input is computed as a Tornqvist index of the asset classes, with their capital service costs as weights. The total cost of capital input is equal to the sum of the costs for the six asset classes.

Labor

Labor input includes the time spent by LEC employees in providing services to LEC customers. It does not include the time installing plant and equipment, since this input is included in the capital input measure. Two groups of employees are distinguished in the TFP study: management and non-management.

The cost of labor input is equal to expensed wages and salaries plus expensed benefits. The total cost of labor is reported in the Form M report. The LECs provided us with a breakdown of labor costs into management and non-management labor costs. The LECs also provided to us total management hours worked and non-management hours worked. The quantity index of labor input is a Tornqvist index of management and non-management hours worked, with management and non-management labor costs used as weights.

Materials, Rents, and Services (Materials)

The cost of materials is equal to total operating expense less depreciation and payments to labor. This information is reported in the Form M. Since the materials data are based on data filed in the Form M, adjustments must be made for the USOAR accounting changes. The two major changes affecting materials are the treatment of nonregulated activities (discussed in our previous section on output) and the shifting of expenditures from the plant and equipment account to the operating expense account (discussed in our previous section on capital input). The LECs provided us the necessary adjustment figures. The Gross Domestic Product Price Index is used to represent the price of materials, since this category is comprised of a diverse set of inputs. The quantity index of materials is obtained by dividing materials cost by its price.

4. Total Output, Total Input, and Total Factor Productivity--Results

The index of TFP is computed as the ratio of the quantity index of total output to the quantity index of total input. Equivalently, the rate of growth of TFP is computed as the rate of growth of the quantity index of total output minus the rate of growth of the quantity index of total input.

Table 1 shows the quantity index of total output, the quantity index of total input, and the TFP index. Also shown are the annual rates of growth in total output, total input, and TFP. Over the 1984-1993 period, total output grew at an average

annual rate of 3.4 percent,[16] total input grew at an average annual rate of 1.0 percent, and TFP grew at an average annual rate of 2.4 percent.

[16]All percent growth rates that we report are computed using natural logarithms. For example, for the average annual growth of output between 1984-1993, 3.4% = ((ln 1.359 - ln 1.000)/9) x 100.

Table 1

Local Exchange Carrier Total Factor Productivity

	Total Output Index	Total Output Growth Rate	Total Input Index	Total Input Growth Rate	TFP Index	TFP Growth Rate
1984	1.000		1.000		1.000	
1985	1.024	2.4%	1.013	1.3%	1.011	1.1%
1986	1.056	3.0%	1.015	0.2%	1.040	2.8%
1987	1.096	3.7%	1.035	1.9%	1.059	1.8%
1988	1.154	5.2%	1.067	3.1%	1.082	2.1%
1989	1.211	4.8%	1.097	2.7%	1.104	2.0%
1990	1.257	3.7%	1.087	-0.9%	1.156	4.6%
1991	1.286	2.3%	1.099	1.1%	1.170	1.2%
1992	1.311	1.9%	1.082	-1.6%	1.212	3.5%
1993	1.359	3.6%	1.093	1.0%	1.244	2.6%
Average Growth 1984-93		3.4%		1.0%		2.4%

5. Conclusion

What are the implications for these results for the price cap productivity offset? Conceptually, the productivity offset in the price cap formula is related to the differential in productivity growth achieved by the price cap local exchange carriers and the U.S. economy. The U.S. Bureau of Labor Statistics regularly publishes TFP growth for major sectors of the U.S. economy.[17] The most comprehensive TFP measure published by the Bureau of Labor Statistics is for the private business sector. Currently, the TFP index for the private business sector is available through 1992. The average annual rate of growth for the private business sector between 1984 and 1992 was 0.3 percent. Thus, the TFP growth differential between the LECs and the private business sector between 1984-1992 was 2.1 percent. If it is assumed that the average annual rate of growth for the private business sector remains at 0.3 percent for the 1984-1993 period, this implies the TFP growth differential is also 2.1 percent between 1984-1993.

[17]The Bureau of Labor Statistics refers to its TFP measures as "multifactor" productivity. These measures are reported in the Bureau of Labor Statistics publication, Monthly Labor Review. The BLS does not currently publish multifactor productivity for the LECs.

Appendix 2

The Relationship Between Output Growth and Total Factor Productivity Growth for Telephone Local Exchange Carriers

The Relationship Between Output Growth and Productivity Growth for Telephone Local Exchange Carriers

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and Mark E. Meitzen
August 17, 1995

I. Introduction

The purpose of this paper is to detail the relationship between output growth and TFP growth when a revenue weighted output index is used in the TFP calculation.[1] The main findings are that when economies of density are present, increases in output growth lead to increases in TFP growth and, conversely, decreases in output growth lead to decreases in TFP growth. In addition to the rate of growth of total output, the sources of that output growth can be an important determinant of TFP growth. When the markup of price relative to marginal cost varies over the services provided, growth in high markup services contributes more to TFP growth than growth in low markup services. Conversely, reductions in the growth of high markup services lead to disproportionate reductions in TFP growth. Much of the increasing competition in local exchange markets is found in high markup services,

[1]The revenue weighted output index is particularly useful in determining productivity offsets in price cap formulas, since it represents a "customer oriented" measure of output. This is because the revenue weights used in the output index represent the relative expenditures made by customers for the respective telecommunications services contained in the output index. The Appendix discusses how TFP constructed with a revenue weighted output index allows one to relate output price changes to changes in input prices and changes in TFP.

such as access and toll. If competition effectively leads to lower LEC output growth in these high markup markets, LEC TFP growth will also be lower.

Section II provides a heuristic discussion of the relationship between output growth and TFP growth. Section III discusses in detail the theoretical relationship between economies of density, output growth, and TFP growth. Section IV reviews the literature on economies of density in the telephone industry. We summarize the results of these econometric studies and report their implications for LEC TFP growth. Section V focuses on particular services provided by the LECs that are subject to emerging competition. These services have high price-to-marginal-cost ratios, and reductions in LEC output growth in these services will likely cause substantial reductions in LEC TFP growth.

II. Output Growth and TFP Growth - Background

TFP growth can arise from various sources. One primary source of TFP growth is technological change, shifts in the production function that allow a firm to use fewer inputs to produce the same amount of output. A second primary source of TFP growth is the exploitation of economies of density through output growth. Economies of density are present when average cost falls as more output is provided over a network of fixed size. Therefore, when economies of density are present, increases in output reduce the average level of inputs per unit of output. Consequently, increases in output growth lead to increases in TFP growth and, conversely, decreases

in output growth lead to decreases in TFP growth.[2] Since the TFP index captures all sources of efficiency improvement--technological change, economies of density, and economies of scale--it is more relevant to the discussion of price caps than is an econometric analysis of technological change.

Prior to divestiture, the telephone industry experienced rapid rates of output growth, and econometric studies of the industry show that this output growth contributed significantly to TFP growth. Since divestiture, the Local Exchange Carriers (LECs) have experienced more modest rates of output growth, and with increasing competition in their markets, they face the prospect of even slower output growth. Because the provision of LEC services is characterized by economies of density, these reductions in output growth will tend to reduce LEC TFP growth.

In addition to the rate of growth in total output, the sources of that output growth can be an important determinant of TFP growth when economies of density are present. In industries with economies of density, prices are typically set above marginal cost for the various services provided by the firm, in order to generate revenue sufficient to cover total cost. When the markup of price relative to marginal cost varies over the services provided, growth in high markup services contributes more to TFP growth than growth in low markup services. Conversely, reductions in the growth of high markup services lead to disproportionate reductions in TFP growth. Much of the increasing competition for Local Exchange Carriers is focused in markets

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[2]Economies of scale and capacity utilization are other potential sources of TFP growth. Empirical studies have not found either to have a significant impact on TFP growth in the telephone industry.

with high price-to-marginal-cost ratios. If competition effectively leads to lower LEC output growth in these high margin markets, LEC TFP growth will also be lower.

III. Output Growth and TFP Growth - Theoretical Framework

Douglas Caves and Laurits Christensen[3] developed a theoretical framework to analyze the relationship between output growth and TFP growth. Their framework is applicable to firms or industries that provide services over a network, such as the telephone industry. Other industries in which the network structure is important are the railroad, airline, trucking, and electric utility industries. TFP growth in such industries can be related to economies of density, economies of scale, capacity utilization, and technological change. Economies of density describe the change in average cost when more output is provided over a network of fixed size. For LECs, network size can be represented by measures such as the number of access lines. When average cost falls as output rises over this given network, economies of density are present. Economies of scale describe the change in average cost when both output and the size of the network increase. If average cost declines when output and network size increase proportionately, economies of scale are present. Capacity utilization describes the impact on cost when capital is not at its optimum level, i.e. the industry has too much or too little capital.

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[3]"The Importance of Scale, Capacity Utilization, and Density in Explaining Interindustry Differences in Productivity Growth," The Logistics and Transportation Review, March 1988, pp. 3-32.